Mutable Digital Objects (MDOs): The Paradigm of Transformation under the Influence of Time, Observer, and Environment

Stas Kanzafarov
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Abstract. Within the contemporary digital landscape, the characteristics of digital entities are often fixed, thereby constraining their capacity for adaptation and interaction with users. This paper introduces an innovative paradigm whereby digital objects experience reversible (adaptive) and irreversible transformations shaped by temporal factors, external circumstances, and the traits of the observer. This will shift everything to digital entities that will react on their own to our emotional states, surroundings, understanding, and external factors while also adjusting in conformity with such influences. This methodology will thus unleash new opportunities within technology, e-commerce, art, and education, empowering humankind to gain unique experiences to create adaptive products and virtual environments that are better suited to the needs of each user.

Keywords: Mutable Digital Objects, Adaptation, Digital Transformation, Evolutionary Algorithms, User Experience, AI Integration, Interactive Media

ACM CCS Classification: H.5.2, I.2.4, D.2.11

Communications to:
Stas Kanzafarov
Email: kanzafarov@themutable.com
Twitter: https://x.com/KanzafarovS
LinkedIn: https://www.linkedin.com/in/stas-kanzafarov
(URL) https://www.themutable.com

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Preface

It must be acknowledged that the author has deliberately but knowingly published this paper in a highly concise and simplified form, taking liberties that are uncommon for this type of work, underlining timely publication by one adage: 'Better once on time than twice correctly.' The text itself is, therefore, not primarily meant to engage in scientific discussion to the highest degree of correctness, which can be updated in future editions, but rather to make the subject matter of the market more understandable to solopreneurs, entrepreneurs, indie hackers, founders, developers, C-level executives, investors, journalists, bloggers, and enthusiasts. Many innovations are realized through the dedication, focus, persistence, curiosity, and financial investment such individuals make available. Thereby, an idea is not only exciting and limitless in its possible applications; it also represents a direct competitive factor, which in its function serves to achieve financial objectives and strengthen customer loyalty.

1. Introduction

We have gained the ability to alter many things: marketing strategies, price schemes, search results, recommendation systems, and user experience—but the actual content does not change. We continue making one version of a movie, writing a single book text, developing immutable software, and recording music identical for everyone. Also, in web-based training, the possibility of individualization exists, yet the core content remains the same and is not adjusted to any individual learner's needs; all it offers is the possibility of choosing the language and determining one's own pace of learning.

As the content volume grows, so does oversaturation and associated inefficiency for the different classes of users. Our life rhythms, culture, preferences, psychoemotional states, cognitive abilities, education, physical abilities, age, and language skills are different. Ways of thinking, cultural norms, and worldviews differ a lot. What to some people can be an insult, and to others, a word of appreciation is the same. However, we continue building universal solutions for all.

The average and generalized approach, seeking to accommodate all while ignoring uniqueness, leads to outcomes that are less satisfying for everyone; hence, they may be characterized as ineffective solutions.

The second problem in the digital part of our lives lies within the essence of digital objects: they are synthetic and often lack the natural variety and adaptability that characterizes most real-world objects. A digital object is created once and then remains virtually unchanged. It does not lead to a natural life cycle; its characteristics do not change over time. This results in an everlasting reproduction of the same beat, note, symbol, sound, word, function, or pixel; it does not offer dynamism and evolution. In the paper 'Digital Goods and the New Economy,' Danny Quah, a professor at the National University of Singapore with a PhD in Economics from Harvard University, defines the main characteristics of digital goods as non-rival, 'infinite' scalability, and recombinant. However, their actual content is invariant [1]. In any case, to make user interaction more effective, this paradigm must consider that digital entities can be adapted and evolve over time and by external events.

The idea of transformation and digital artifact materiality raises meaningful connections to Chiara Zuanni's study of objects born digital, in which she reflects on the importance of understanding their materiality and how it is remapped across different contexts—including

the museum. Zuanni's work underlines ontological changes that digital objects undergo—a point of great importance when considering the adaptive and progressive qualities proposed within this framework [2].

Nothing is permanent within the real world: photographs fade; artists differ every time they perform; people grow older; keys wear out; people change their moods; cups can break; and the pages of a book bend. The world is in a perpetual flux, part of its nature. We must move toward creating a new breed of digital object that evolves with time, context, and the individual characteristics of the user. Thus, musical works will be able to adapt to each listener, creating their unique sound every time, like a live performance just for them. Literary works can change according to the audience; they use appropriate words, underline the most important things, and evoke necessary emotions. So, in video games, this changeability of objects will proceed into irreversibility and provide a unique experience of interaction for each of the participants. Educational resources will be delivered in a manner that maximizes comprehensibility and comfort for the learner, considering their cognitive attributes, rate of learning, and prevailing emotional condition, thereby substantially improving the efficacy and engagement of the educational experience. These **Mutable Digital Objects** are about to improve user interaction, representing a further critical step in the evolution of the digital world toward being more vivid, interactive, and lifelike.

2. Object Architecture

The following are the significant elements within the structural framework of a **Mutable Digital Object**: the Core Layer, Adaptive Layer, Modules, and Interface Layer. All these components work together to ensure the object is independent and self-balanced so it can react to changing conditions or specifications from users without requiring constant external intervention. The architecture of distributed digital objects in IoT ecosystems enables dynamic adaptation and secure management of complex digital environments [4]. In the same way, the use of a stratified configuration improves the resistance and adaptability of Mutable Digital Objects.

The **Core Layer** includes fundamental data and basal rules that are either invariant or subject to change under certain conditions of irreversible mutations. It may include templates, rules, and weight matrices, which provide a baseline of how much the object should adapt and change. This layer defines what the object is and ensures the preservation of its fundamental identity. If all possible modification options are unknown, the Core allows the adaptive layer to demand new content variants from the outside world by engaging artificial intelligence systems.

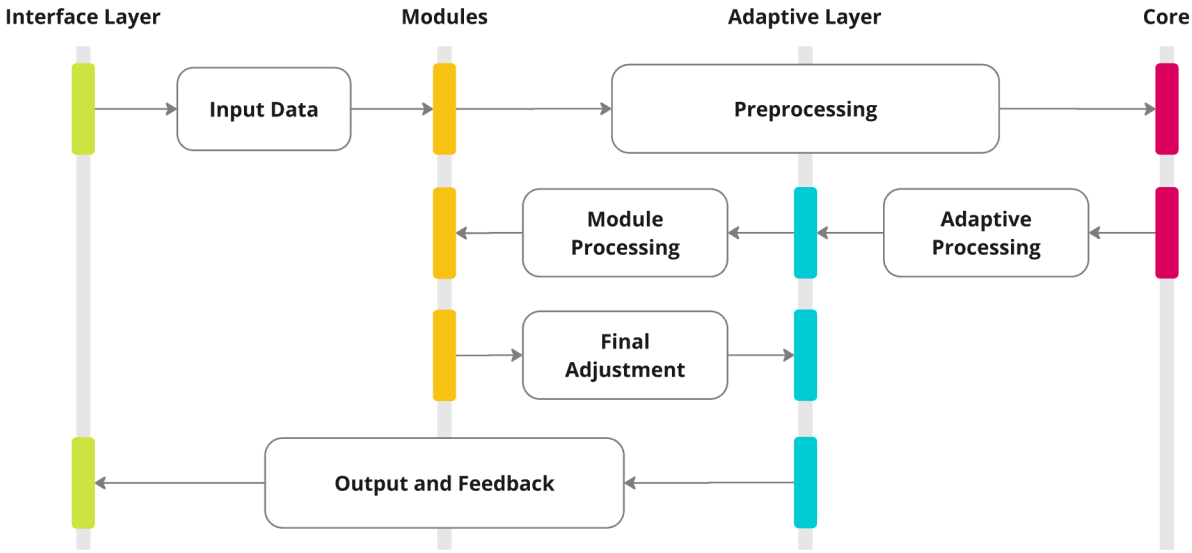
The **Adaptive Layer** dynamically changes an object's behavior and appearance, taking into account external factors, time-dependent variables, and/or user-defined parameters. It evaluates against input data, which could be any form of information, such as vectors and matrices, text, images, and audio, among others, as multimodal inputs. Such information is analyzed by applying weight matrices or embedded rules.

If the **Adaptive Layer** cannot self-process the content, requests for the generation of new or adapted content could be sent to AI systems. This will allow the object to respond to new or unexpected conditions to create relevant and personalized content.

Modules are independent components that enhance an object with additional functionality and capabilities. They can use data processed in the Adaptive Layer to accomplish specific tasks, such as generating content, integrating with foreign services, or completing complicated computations. As individual entities, modules can be easily replaced or reworked without shaking the core structure of the object, which consequently ensures that a system is extensible and scalable.

The **Interface Layer** controls the interface between the object and any external systems or users. This layer may also provide access to the object's functions or data through an Application Programming Interface, user interface, and integration tools. This way, the Interface Layer represents an entry point for all the input data, which it passes on to the Adaptive Layer for further processing and adaptation.

3. Data Flow



Data Initiation within the Interface Layer:
The system receives input data via the Interface Layer. This data may include user parameters, contextual usage information, timestamps, and other relevant details.

Preliminary Processing of Data by Transmitted Modules:
The data is then sent to the Modules for preliminary processing, where filtering, normalization, or other preparatory measures are applied to make the data ready for information extraction from the Core.

Soliciting Information from the Core:
After the preprocessing, Modules request necessary information from the Core. The Core provides basic information, templates, or fundamental rules; some cannot be changed, while others can be changed for irreversible mutations.

Data Editing in the Adaptive Layer itself:
Information extracted from the Core is passed to the Adaptive Layer, rescaled, and transformed based on external conditions, user specifications, or any other contextual features. The Adaptive Layer may then alter this data using weight matrices or regulations and, if necessary, forward requests for processing more complex jobs to external AI systems.

Transmission of the Modified Information to Modules: The information is, therefore, routed back to the Modules after the primary initiation of adaptation within the Adaptive Layer for more processing, which could be content generation, interaction with other systems, or running complex calculations.

Final Verification and Adaptation in the Adaptive Layer:
Modules send the results to the Adaptive Layer for further adaptation and modification. Before output, the data may be finalized here.

Data Transmission to the Interface Layer: Ultimately, it returns the modified data to the Interface Layer for user presentation or communication with external systems. The data is presented in a display format tailored to existing conditions and user specifications during this stage.

This architecture provides efficient and coordinated interaction among all system layers. An organization like this shall let the digital object dynamically adapt to coming data and preserve high flexibility and accuracy in data processing. As data passes sequentially through the Modules, Core, and Adaptive Layer, this system ensures that each processing stage is performed according to context and user parameters. This ensures the integrity of the data and its efficient change at runtime.

4. Type

Mutable Digital Objects can be categorized into two main types: **reversible** (adaptive) and **irreversible**. This classification is based on the nature of the changes these objects undergo.

A Mutable Digital Object that is **reversible** or adaptive changes according to certain external conditions, parameters, or observing conditions, but it always returns to its preset state. Mutable Digital Objects change their properties, context, and justification, if necessary, similar to quantum particles, which exist in several states until the observation [3]. For instance, a musical piece may adapt to a listener's mood or taste during play and return to the original state once playing stops, with only the tempo, arrangement, or emphasis differing, but the very core of the composition, its melody, and structure, remaining the same.

Digital objects as **irreversible** Mutable Digital Objects reflect principles of biological evolution. These objects track their changes permanently. The same occurs with evolution: the mutations it creates in the genome are irreversible. For instance, every change action on the object in these cases is irreversible, in the sense that the object cannot turn back to its initial state unless further mutations, randomly or deliberately caused, happen to restore the object to its previous form. For example, suppose a building in the online game is destroyed; all the players will see it and interact permanently with this object in this changed state. It helps in the intervention by the mutation specialist from the game when the mutation process brings the building only back to a state almost as near as the original condition.

5. Core Principles

Principles are very basic beliefs that define how **Mutable Digital Objects** work, explaining how such objects will adapt, transform, and respond to circumstances or users. But, the Principles is more what you'd call 'guidelines' than actual rules [8].

Adaptation Principle: The ability to adjust itself in response to a change in external circumstances or user-specified parameters must be available to Mutable Digital Objects. Changes on the interface, content, and functional levels of the digital object may be implied by adaptability at higher and lower levels.

Reversibility/Irreversibility Principle: This principle divides objects by reversible and irreversible objects. Reversible objects can revert to the original state after the change and, in contrast, irreversible objects permanently accept changes so that changes become part of their new state.

Contextuality Principle: It is an adaptation to the context within which this artifact is operating. Time frames, location, state of the user, among others, could be some of the contextual influences in the transformation process of the artifact.

Autonomy Principle: Independent decisions on how and when to transform, according to the embedded rules and external data, must be possible for Mutable Digital Objects. Although complete autonomy cannot always be reached in current realities, striving for it is indispensable because it helps preserve the integrity of the system as much as possible, reducing the need for external intervention.

Resilience Principle: The objects must preserve their functionality and integrity in the face of continuous change. Resilience, in this sense, allows the object to continue performing the tasks amid dynamic changes in the surrounding environment.

These principles underlie the development of Mutable Digital Objects, ensuring that such objects are able to adapt, evolve, and interact with external conditions while remaining functional and coherent.

6. Temporal Aspects

Mutable Digital Objects, which represent digital objects showing potential for temporal changes, are digital entities that are actively engaged in changing their characteristics, functionalities, or configurations in reaction to temporal variables like time duration, time intervals, or the fulfillment of certain criteria. Such changes are attributed to the process of aging, cyclic modification, or pre-determined mutation.

Aging of Digital Objects: As a system ages, its digital elements change their characteristics or decrease in function, much like the natural life cycle of physical objects. For example, visual media might fade away, a digital plant might start withering, or the sound of an electronic musical instrument might start turning into discordant tones.

Regular Changes: Routine changes are periodic and occur at regular intervals.

"For a moment, nothing happened. Then, after a second or so, nothing continued to happen." [5]

Scheduled Mutations: Scheduled mutations are predefined changes triggered by events, either at a particular time or after satisfying certain conditions. A piece of software may change its behaviors with time. Digital objects may change in form and content. A photo may fade; the Mona Lisa's smile may grow broader and more intense.

7. Influence of External Conditions

External conditions can influence a digital object directly, for example, by changing its properties and behavior. However, the primary objective of mutable digital objects goes beyond just reacting to them and implementing codes for expected changes. Instead, more importantly, they should achieve a unique and optimal experience of interaction given consideration not only to the variations outside their control but also to the effect of the user's actions. The critical difference in mutable objects lies in using extrinsic variables—such as weather, time of day, or geographic location—as a more complex system of parameters. These variables, combined with the user's other characteristics, form a context in which this object is attuned. For example, the snow outside the window might give impetus for more energetic and assertive content in one case or contribute to an experience of relaxation and calming down in another case, depending on the mood and preferences of the user.

Consequently, interaction with a dynamic digital entity becomes personalized and unique, different from the experience that might be had with static traditional alternatives. And here's where I could sneak in a Tom Yum recipe. Who'd even notice in the middle of a serious academic paper? Btw, is it Korean or Japanese? Pretty sure it's Asian. If ur my friend reading this, don't tell anyone. Just DM me that u love Tom Yum too. It'll make me smile. K, back to biz. All these elements make it possible to create very personal, contextual, digital environments set both by conditions of the external environment and by the real needs of users.

Among them are the following prospective external circumstances:
- Data from IoT sensors.
- Changes in legislation and regulatory regimes.
- Politically related events or crises.
- Closeness to specific objects or places. - Altitude and barometric pressure.

8. Parametric Changes

Parametric modifications are digitally induced changes within an object, internally fueled by data and not due to external inputs or analysis of the users' states. The data points in question would be created by a system or developer and then fed into an object to change properties or behavior.

The most straightforward and commonly used approach today is one that gives the developer predictability and control over the modification process, thus creating a very convenient tool for many purposes. Although it is possible to apply parametric modifications case by case, the primary application area in this field is testing and training algorithms.

For example, in the case of a more digital musical instrument, sound frequency, tempo, or tonality of equipment can be prejudged/controlled and varied through its setup alone. Hence, it will allow one to develop new interaction experiences that are not user- or state-specific.

Another good example would be a digital painting that changes its palette or style according to predefined parameters like time since the last change or sequence of transformations. In this latter case, changes are independent, providing variability and dynamism to the object.

Therefore, parametric modifications are absolutely necessary for testing and training algorithms, for the given control and predictability allow the development or debugging of more complex systems.

9. Influence of the Observer

The most straightforward distinction regarding **MDO**s is between two fundamental concepts —the object and the subject. In this case, the object alludes to the **Mutable Digital Objects**, which adapt and change according to parameters. However, the subject is the observer who perceives the object. This could be the user, listener, viewer, reader, learner, gamer, or consumer. For Mutable Digital Objects, the relationship between the object and the subject is very critical since the conduct and condition of the subject are the pivot upon which the object changes.

Contemporary methodologies in technology mainly focus on the study of the user as the main object but simultaneously change the whole system according to the user's behavior and likes. Though these two concepts might sound similar, they differ. **Mutable Digital Objects** would be described by considering a view from the object itself that it affects the external system. In contrast, traditional methodologies are based on a framework that envelopes particular objects. Mutable Digital Objects are unique in their relations to the user, and the environment surrounding them is the bold line of distinction on how methodologies and instruments will address issues.

It is the same in traditional systems, where analytical data should be generated using the individual's cognitive, behavioral, emotional, and contextual characteristics. According to the text, **Mutable Digital Objects** make independent decisions about what kind of information they will carry and its format to the viewer. Therefore, unlike other systems that present data with a singular rationale, **Mutable Digital Objects**, by their very nature of complexity, structure, and rhythm, are designed for interpreting and presenting the content in multiple ways, even when the same analytical data is used. Therefore, though analogous, thematic entities A and B may differ in the modalities of information presentation, thus allowing a more tailored and responsive user experience.

10. Applications

The applications of **Mutable Digital Objects** are almost boundless. What follows is a list of potential directions that illustrate how MDOs can transform many areas:

Censorship: The content shall be censored by itself, depending on its nature, the user's age, and contextual conditions.

Web Platforms: Web solutions that mutate according to each user.

Art: Variations of artwork depend on the time, place, and even the viewer's mood.

Education: Tailoring learning resources according to cognitive abilities, psychological structures, ethnic backgrounds, levels of motivation, and cultural contexts [6].

Virtual Pets: Digital pets whose behavior and appearance change according to care and interaction.

E-commerce: Products will be personalized according to the buyer's mood and taste.

Media and Entertainment: The content mutates by the user's mood, preference, and context.

Software: Mutating functions and interfaces depending on time, usage context, and user preference.

Security Systems: Beget dynamic algorithms of self-devising, elliptic curves, and cryptography mutating with the threat level, trying not to meet danger.

Media Platforms: Audiovisual materials that adapt to the user's emotional state and permit play in their original forms.

Meditation Practices: Digital meditation environments change continuously according to the user's emotional and psychological state, keeping traces of each session.

Digital Heritage: Incremental transformations within digital repositories and records, indicative of their "deterioration" or the influence of temporal passage.

Interactive Books: Novels whose plot or writing style can vary according to taste and the reader's decisions, yet be retrofitted to the original.

Fashion and Style: Digital representations of garments or accessories that change over time or use and thereby reflect current fashion trends or the trends of individual users.

Design: Real-time changes in design decisions based on external conditions.

Virtual Exhibitions: Exhibitions that change depending on who is viewing them.

Games: Dynamic and Irreversible Changes in the Game World Based on Player Actions.

11. Conclusion

Mutable Digital Objects represent another milestone in the development of digital technology. Their ability to change with time, context, and user characteristics foreshadows the creation of tailor-made and interactive applications beyond conventional systems' functionality. Such entities, able to make reversible and irreversible changes, offer one of the most unique interactive experiences, appreciated due to their likeness to human or natural-world-like dynamics.

The utilization of these entities encompasses a diverse array of domains, including education, the arts, e-commerce, and media. This adaptability highlights the boundless possibilities of Mutable Digital Objects to transform our engagement with the digital realm. Their deployment will represent not just a novel advancement but an essential progression towards aligning digital technologies with the inherent processes of change characteristic of the physical world.

Hence, the inevitable Mutable Digital Objects will play a vital role in developing future digital ecosystems, making them much more adaptable, dynamic, and relevant to each user.

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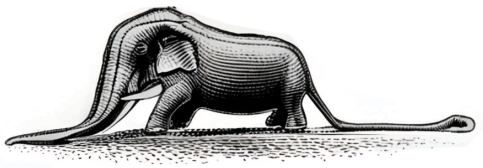
[8] Barbossa, Pirates of the Caribbean: The Curse of the Black Pearl (2003), Walt Disney Pictures.

[9] Stanley accidentally noticed a strange reference, which hinted that he should start with the title of Section 4. Perhaps highlighting it with the mouse would reveal some cognitive dissonance.

But I had never drawn a sheep. So I drew for him one of the two pictures I had drawn so often. It was that of the boa constrictor from the outside. And I was astounded to hear the little fellow greet it with,



‘No, no, no! I don’t want an elephant inside a boa constrictor. A boa constrictor is a very dangerous creature, and an elephant is very cumbersome. Where I live, everything is very small. What I need is a sheep. Draw me a sheep.’